DOCUMENT RESUME

ED 17 974 CE 021 647

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TITLE	A Model for Planning Vocational Education Via Mathematical Modeling. (Technical Report).
INSTITUTION	Ohio State Univ., Columbus. National Center for Research in Vocational Education.
SPONS AGENCY	Bureau of Occupational and Adult Education (DHEW/OE), Washington, D.C.
PUB DATE	Jun 78
NOTE	29p.; Paper presented at the National conference, "Improving State Level Vocational Planning and Evaluation," (Columbus, Ohio, (February 5-8, 1978)
EDRS PRICE	MF01/PC02 Plus Postage.
DESCRIPTORS	*Computers; *Mathematical Models; Objectives; Operations Research; Postsecondary Education; Problems; Program Improvement; *Program Planning; Secondary Education; *Vocational Education

ABSTRACT

A project was developed to link together the computer and an operations research technique (goal programming) and to bring them to bear on problems in improving vocational education planning. The process involves using the computer to solve a mathematical model designed to determine trade-off values among alternative goals and plans. Simulating the relationships among goals, constraints, and variables enables the planner to explore the effects of alternative actions. Typical vocational education goals center on training-related placements, completers' labor force participation, number of students to be served, completers' continuing education, completers' wages, dropout reduction, increasing employment options, serving disadvantaged/handicapped, eliminating sex stereotyping, and social-political goals. Constraints include limited job openings, limited budget/facilities, students available, and student interest. Decision variables, goals, and constraints are placed into an equation. The final step in developing the model is the formulation of an achievement function. Steps involved in model application are: identify goals and constraints, gather relevant data, put data into computer, apply the model, and interpret the results. The model is applicable to planning at the state level (for example, it was applied in Missouri) or regionally within the state. (CSS)

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A MODEL FOR PLANNING VOCATIONAL EDUCATION VIA MATHEMATICAL MODELING (Technical Report)

by

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A paper presented at a national conference "Improving State Level Vocational Planning and Evaluation" held February 5-8, 1978 in Columbus, Ohio

The National Center for Research
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1960 Kenny Road
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June 1978

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
NATIONAL INSTITUTE OF EDUCATION

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The material in this publication was funded by an Education Professional Development Act (EPDA), Part F, Section 553 Grant, administered through the Vocational Education Personnel Development Division, BOAE/USOE, Region V Office, USOE, and the Division of Vocational Education of the Ohio State Department of Education. Contractors undertaking such projects under government sponsorship are encouraged to express freely their judgment in professional and technical matters. Points of view do not, therefore, necessarily represent offical BOAE, USOE, or State of Ohio position or policy.

FOREWORD

Vocational education is under a great deal of pressure to do more scientific planning. We are operating in an age of specificity brought about at least in part by a changed technological society. P.L. 94-482 and its supporting rules and regulations lend emphasis to the need for upgrading the vocational planning process.

The adequate planning of local vocational programs begins at the state level. Planning needs must be determined, data collection methods standardized and planning output shared. All this precision calls for a high level of organization.

This document is an effort at providing guidance to state level planners as they strive for organization and precision in the planning process. The paper is the work of James W. Atteberry, formerly a research specialist at the National Center for Research in Vocational Education. It was presented at a national conference, "Improving State Level Vocational Planning and Evaluation."

The contents should be regarded as being highly theoretical since the model has not been tested under practical conditions. The principal value of this work probably rests with the fact that it can serve as a base document for planners who wish to pursue mathematical modeling as a basis for decision-making.

Appreciation for their contributions to the production of this document is extended to James Atteberry, the author, and to Daniel E. Koble, Jr., the project director who provided counsel and advice throughout its development. The staff of the National Center hopes these ideas will open new horizons for planning technicians in vocational education.

Robert E. Taylor
Executive Director
The National Center for
Research in Vocational Education

INTRODUCTION

For those who labor in the discipline of vocational education, the mandate in the 1976 vocational legislation calling for improved planning does not come as a surprise. It could have been predicted. Certainly reports like the National Advisory Council Report of 1965 and the General Accounting Office Report of 1974 foreshadowed this mandate. The question that comes to mind, then, is, "Why has vocational education apparently not responded to past efforts aimed at improving planning?" If improvement is to be made we must seek answers to this question.

There are many possible answers. Stevens (1976) hypothesizes that the existence of a laissez-faire educational system creates disincentives to plan. The GAO Report (1974) claims that the federal government has neither supplied the "carrot" nor the "stick" to bring about improved planning. And, of course, the lack of a unified system of vocational education has been cited by some as precluding the sort of planning desired (Mangum, et al., 1969).

To these hypotheses I would add one more. Improved planning has been slow because of a failure to either develop or employ the tools or techniques that would help us improve the process.[1] For example, the full potential of the computer has not been realized. The same can be said about the use of operations research techniques. In contrast, consider how business and industry have made extensive use of techniques such as linear programming (Dangig 1973), mathematical simulation (Forrester 1961), and goal programming (Lee 1972). Certainly these methods have greatly improved their ability to plan and make decisions. Then why not expect the same results in vocational education? Very simply then, the purpose of this document is to link together the computer and an operations research technique and bring them to bear on the problem of planning vocational education. Precisely how this is done becomes the focus of the rest of this paper. But keep in mind that the system presented herein addresses only one aspect of the problem of improving vocational education planning.

Overview of the Planning Model

In the planning of vocational education, the administrator either explicitly or implicitly makes decisions that involve multiple and conflicting goals. For example, consider the conflict in goals that occurs when one tries to meet manpower needs, serve disadvantaged students, and maximize training-related placement all at the same time. By some process, be it recognized or not, one must prioritize such goals and determine the trade-offs before making a decision. The planning model which is contained herein simply makes this process more rational and explicit.

This is done, in part, by using the computer to solve a mathematical model which has been designed to determine the trade-off between alternative goals and plans. Simulating the relationship between goals, constraints, and variables in such a model enables a planner to use the model instead of the actual system, to explore the effect of alternative plans and decisions. Ultimately a plan is arrived at that maximizes the system goals while avoiding the excessive costs that result if such plans were tested on the actual system. Analogous to the use of a model in this fashion are the models that aeronautical engineers employ in the design and testing of airplanes.

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[1] We should not be surprised to find that all of these hypotheses contribute to the problem. Unfortunately, very little empirical evidence exists regarding the causes.

Development of the Mathematical Model

The mathematical model is based on an operations research technique called goal programming. This technique allows one to solve problems involving multiple and conflicting goals and is ideally suited to the sort of planning problems that vocational administrators face. The task ahead then is to describe how this technique is used to develop the mathematical model employed in the planning model.

Indentification of Goals and Constraints

The first step is the identification of goals and constraints. Goals, are something toward which effort or movement is directed while constraints serve to restrict such effort or movement. To say that there is one set of goals and constraints applicable to all vocational systems is ludicrous, for the needs to be met vary from one situation to another.

Elbert (1976) dealt with this problem of goal congruence and came up with the list of goals and constraints presented in Table 1. This list was found to be the most comprehensive and at the same time the most congruent in the opinion of over 400 administrators, teachers, clients, and constituients surveyed. In turn, this list became the point of departure in forming the mathematical model.

Mathematical Formulation

Given these goals and constraints, the next step is to express them in mathematical terms. An equation which describes the functional relationship between each goal or constraint of the system and the decision variable has to be formed. Decision variables, are those parameters that can be more or less controlled by the decision maker; examples are: the number of programs, program completions, and enrollment.

Stated another way, if each goal is designated as G_i then each objective function, in turn, can be expressed as a function of the decision variable, that is: $G_i = f_i(X_j)$ where $f_i(X_j)$ is the function of the decision variables associated with the i^{th} goal. Thus, to say that we are going to formulate each objective function $f_i(X_j)$ means that an expression is constructed that represents the contribution which particular program choice (X_j) makes to the goal under consideration.

Each objective function must be constructed so that:

$$f_i(X_j) \lesseqgtr b_i \qquad (1)$$

where b_i is the associated right-hand-side value and reflects the value of the goal that must be satisfied. Each objective function will have either a positive or negative deviational variable d^- or d^+. Consequently, each objective function is of the following form:

$$f_i(X_j) + d^- - d^+ = b_i \quad (i = 1, 2 \ldots M) \qquad (2)$$

where d^- or d^+ represent the underachievement or overachievement respectively of each goal.

An example of the formulation of an objective function should clarify this discussion. Consider how one might formulate an objective function to represent the goal of maximizing the number of training-related placements. Mathematically, the objective function would appear as:

Table I

Typical Goals of Vocational Education

Goals center on:	Constraints include:
• training-related placements	• limited number of projected job openings
• labor force participation of completers	• limited budget
• number of students to be served	• limited facilities
• completers continuing education	• students available
• wages of completers	• student interest
• reduction of dropouts	
• increasing employment options	
• serving disadvantaged and handicapped	
• eliminating sex stereotyping	
• social-political goals	

$$\sum_{j=1}^{N} P_j X_j + r^- = TR \qquad (3)$$

In this equation, the TR value represents the goal of placing completers in training-related occupations. The X_j values are the decision variables and are the number of completers from each program. The P_j values (technological coefficients) are the expected placement rates, derived from historical data, for each program. Since overachievement of the goal is acceptable, the deviational variable in this equation can be represented by the r^- value. If underachievement of the goal is acceptable, then the deviational variable would be positive and represented as r^+ in the equation.

To sum up the steps involved in the formulation of an objective function, first, the level of the right-hand-value for each goal must be set by the decision maker followed by a decision as to whether overachievement or underachievement of the particular goal is desirable. This data must be gathered to derive the technological coefficients which depict the relationship between the decision variables and the particular goal.

After studying the previous example, turn to the actual mathematical representation of each objective function. First examine the variables, goals, and technological coefficients as defined in Table 2; then, proceed to the mathematical formulation of each objective function.

A. Training-related placements

$$\sum_{j=1}^{N} P_j X_j + r^- = TR \qquad (4)$$

This equation is identical to the example (see equation 3) and makes it possible to specify a program mix that maximizes training-related placements.

B. Labor force participation level

$$\sum_{j=1}^{N} LFPR_j X_j + f^- = LEP \qquad (5)$$

Certainly the labor force participation of vocational education graduates is an indicator of program effectiveness and thus is included in the model. This ojective function allows the decision maker to plan for the allocation of resources so that the number of completers who are part of the labor force is maximized.

C. Number of students served

$$\sum_{j=1}^{N} A_j X_j + s^- = SS \qquad (6)$$

By using this objective function, it is possible to specify either a minimum or maximum level of students to be served by the vocational education system.

Table 2

Variables, Technological Coefficients, and Goals and Constraints Defined

Variables

X_j = number of completers per program (j=1 . . . N)

Technological Coefficients for Each Program j

P_j = estimated training-related placement rate

$LFPR_j$ = labor force participation rate of completers

BS_j = percent of completers continuing education

W_j = average wage or salary for completers

SL_j = index of the substitutability of skills

DR_j = dropout rate

C_j = cost of a completer

TS_j = teacher student ratio

F_j = facilities requirement

DIH_j = percent of completers who are estimated to be disadvantaged & handicapped

SEX_j = index of ability to eliminate sex stereotyping

L_j = length of time required to train a completer

SI_j = index of student interest

A_j = ratio of enrollment to completions

Goals

TR = desired training-related placements for the area or state

LFP = desired number of completers in the labor force

SS = desired number of students to serve

CE = desired number of students continuing education

INC = desired income level which should be exceeded

OPT = desired level of options available to completers

DIH = level of disadvantaged & handicapped to be served

SEXS = level of non-traditional completers

CL = desired level of completions from each program

DO = acceptable number of dropouts

Constraints

PO_j = projected occupational openings for each program

BUD = budget

TA_j = projected supply of teachers for each program

FAC = facilities available

PE = estimated students available

SIL_j = minimum student interest which must exist

D. Continuing education

$$\sum_{j=1}^{N} BS_j X_j + p^- = CE \tag{7}$$

Although immediate employment in the occupation in which the student is trained is preferred, vocational education often motivates students to continue education at a higher level. This objective function enables the decision maker to specify the number of completers who continue education.

E. Income of completers

$$W_j + wa_j^- = INC \quad (j=1 \ldots N) \tag{8}$$

Since the training of students in low-wage-paying occupations makes it difficult, if not impossible, to realize any net benefits over costs, occupations where the wage is below a desired level should be identified. This objective function makes that possible.

F. Completers option

$$SL_j - sl_j^+ = OPT \quad (j=1 \ldots N) \tag{9}$$

Rapid changes in technology often make skills obsolete; thus, it is important to provide training that increases the students' options for finding employment. By measuring the transferability of skills from one occupation to another, the decision maker can discriminate programs relative to their ability to increase employment options. Then, through the use of this objective function, the decision maker can specify a minimum level of options that each program should provide and screen programs accordingly.

G. Dropouts

$$\sum_{j=1}^{N} DR_j X_j + do_5^- = DO \tag{10}$$

This function reflects the goal of reducing the number of students who dropout of vocational education programs. Since vocational programs differ in their ability to retain students, it is obviously important to establish a mix of programs that minimizes the students dropout rate.

H. Disadvantaged and handicapped

$$\sum_{j=1}^{N} DIH_j X_j + dh^- = DIH \tag{11}$$

Federal law requires that vocational education serve disadvantaged and handicapped students. This objective function allows the decision maker to establish the level of disadvantaged and handicapped students who need to be served in each program.

I. Sex stereotyping

$$\sum_{j=1}^{N} SEX_j X_j + se^- = SEXS \qquad (12)$$

The 1976 vocational education legislation seeks to eliminate sex stereotyping in vocational education. Since certain occupations lend themselves more readily than others to such efforts, analytical methods can be employed to identify these occupations. Once this is done the decision maker can plan the allocation of resources so that sex stereotyping is reduced.

J. Social-political constraint

$$X_j + cl_j^- = CL \quad (j=1 \ldots N) \qquad (13)$$

The decision maker may want to guarantee the current level of some programs for social-political reasons — even though other considerations might force these programs out of an optimal solution. This objective function makes it possible to include such an objective in the model, thus guaranteeing the continuation of desired programs at any designated level.

K. Projected occupational openings

$$P_j X_j - po_j^+ = PO_j \quad (j=1 \ldots N) \qquad (14)$$

If the ratio of the number of completers relative to the projected openings for a program area is large the probability of a training-related placement is low. This objective function limits program completions to projected openings that need to be met by vocational education and serves to increase the probability of placing completers in training-related occupations.

L. Budget

$$\sum_{j=1}^{N} C_j X_j - b^+ = C_j X_j - b^+ = BUD \qquad (15)$$

This objective function limits expenditures to the resources available for vocational education in the state.

M. Teacher supply

$$TS_j X_j + te_j^+ = TA_j \quad (j=1 \ldots N) \qquad (16)$$

The delivery of vocational education programs is constrained by the availability of teachers. By including this objective function in the model, it is possible to identify vocational areas in which additional teachers need to be trained.

N. Facilities

$$\sum_{j=1}^{N} F_j X_j - fa^+ = FAC \qquad (17)$$

There is, at any point in time, a limited number of classroom or shop facilities in which vocational education can be taught. Thus, this constraint must be considered in the planning of vocational education programs.

O. Projected enrollment

$$\sum_{j=1}^{N} L_j X_j - e^+ = PE \qquad (18)$$

There is a limit to the number of students who can receive vocational education. At the extreme, secondary vocational education cannot exceed school enrollment at that level. At the postsecondary and adult level the limit may be less obvious. In any case, the decision maker, through the use of this objective function, can specify the limits which the enrollment in vocational programs should not exceed.

P. Student interest

$$SI_j X_j - si_j^+ = SIL_j \quad (j=1 \ldots N) \qquad (19)$$

Obviously, enrollment in each program is limited by student interest. Although student interest may be difficult to measure, this objective function makes it possible to screen programs on the basis of the interest that exists.

Achievement Function Formulation

The final step to the development of the mathematical model is the formulation of an achievement function which contains the deviational variables (d^+ or d^-) representing each goal or constraint. Mathematically, the achievement function can be represented as:

$$\text{MINIMIZE } Z = \sum_{j=1}^{N} (d^+ + d^-) \qquad (20)$$

subject to

$$AX - Id^+ + Id^- = b$$

$$X, d^+, d^- \geq 0 \qquad (21)$$

where the goals are expressed by the column vector b ($b_1 \ldots b_m$). In the equation, A is an M x N matrix of technological coefficients expressing the relationship between the decision variable (X) and the goals. The deviations from the goals, which are to be minimized, are represented by the d^+ and d^- m-component vector. Finally, I represents the identity matrix in m-dimensions.

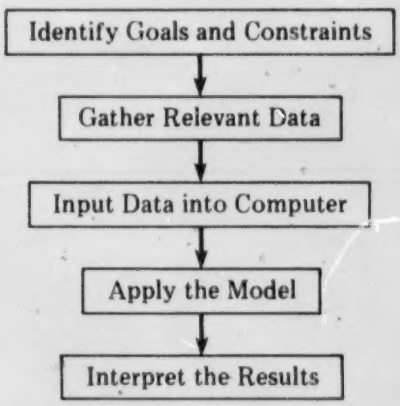
To use the goal programming technique, each goal must be analyzed as to whether the over- or underachievement of the goal is acceptable. From this analysis, + or - deviational variables are assigned to each goal. Next, the goals of the particular system are ranked according to their importance. Each goal is then assigned a priority factor that determines the sequence in which that goal is entered in the model. By assigning a priority factor to each goal, one can guarantee that the most important goal is achieved to the extent desired before the next goals are considered.

Obviously, one does not know *a priori* what the goals or their priority might be. Thus, the achievement function cannot be entirely formulated beforehand. This does not pose a problem, however, for there are only a few things that need to be done to complete the achievement function. These steps will be made clear in the application section.

To sum up, the mathematical model has been formed and is now ready to be used in the application of the planning model.

Application of the Planning Model

To restate, the formulation of the mathematical model employed in the planning model has been completed and is ready to be used. Perhaps it would be clearer to present a schematic of the steps involved in the application of the model.



The first step is the identification of goals and constraints. As you recall, there are ten possible goals and six constraints from which we may choose. These choices are presented in Table 3. Once these choices have been made, the next step is to rank order the goals and constraints and then assign the appropriate priority level to each.

Following this, the data which are relevant to the goals and constraints must be gathered. Then these data become input to the computer.[2] Finally, the mathematical model is applied and the results are interpreted.

This model is applicable to planning at several levels. It can be used in planning at the state level or for regions within the state. It can also be used to include a portion of the delivery system, say for secondary vocational planning or postsecondary planning.

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[2] How to input the data into the computer is not illustrated in this paper, but the directions and computer programs are available upon request.

Table 3

The Planning Model's Goals and Constraints

Ranking	Assigned Priority Level	Deviation to Minimize
Goals		
Maximize training-related placements	—	r^-
Maximize income of completers	—	wa_j^-
Maximize students served	—	s^-
Maximize labor force participation	—	f^-
Maximize completers' options	—	sl_j^+
Minimize dropouts	—	do^-
Desired level of completers continuing education	—	p^-
Elimination of sex stereotyping	—	se^-
Level of disadvantaged & handicapped	—	dh^-
Guarantee current program operation	—	cl_j^-
Constraints		
Limit on projected openings	—	po_j^+
Limit on budget	—	b^+
Limit on projected enrollment	—	e^+
Limit on student interest	—	si_j^+
Limit on facilities	—	fa^+
Limit on teachers available	—	te_j^-

A major limitation of the model, however, is that it has been formulated with a single set of decision variables in mind. That set includes only the vocational programs[3] that one might consider offering. The rationale underlying the model is based on the assumption that most of the planning decisions to be made can be thought of as ultimately making a choice among different programs to offer.

Application of the Model in Missouri

Now let us turn to the actual application of the model to the Missouri System.[4] First the goals and constraints that depict the system of vocational education were identified and ranked according to their importance. From Table 4, one can see that only five of the possible ten goals and three of six constraints were deemed appropriate to the planning problem in Missouri.[5]

From the Table, you will also note that the goals and constraints have been quantified, simply by assigning a value to the goal.

Next a priority level is assigned to each goal and constraint. In studying Table 4, you will note that the assigned priority levels correspond directly to the ranking that the goals received; note, however, that all constraints are assigned the highest priority level P_1. Obviously, constraints should receive the highest priority because they are more rigid in the sense that they are nearly impossible to change during a planning cycle. In other words, constraints are the "givens" within which every planner or decision maker must work. Goals, on the other hand, are those things that one is trying to accomplish and are not as rigid. As a rule of thumb, understand that constraints are always assigned priority level 1 (P_1). In turn, the goals are assigned a priority level in accordance with their importance to the system. For example, the highest ranking goal is assigned P_2, the next highest goal P_3, etc.

Understand, of course, that the purpose for assigning priority levels is to tell the mathematical model the sequence in which the goals are to be accomplished. In this example, this means that by assigning the highest priority to the goal of increasing training-related placements, the model will seek to accomplish that goal before attempting others.

Perhaps it would be helpful to present the mathematical representation of the objective functions and achievement function resulting from these steps. Mathematically, the objective functions appear as:

$$X_j - po_j^+ = 0_j = 27{,}022 \quad (j=1 \ldots N) \tag{22}$$

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[3] A vocational program is a course of study designed to prepare someone for a specific occupation, i.e., welding, secretarial work, plumbing.

[4] The application was done under a Part C research grant while I was a member of the faculty at the University of Missouri-Columbia. It was done to determine the feasibility of such an approach. While the application of the model was made possible by the gracious support and cooperation of the State Department of Education in Missouri, one should not interpret the discussion of the results as reflecting either the plans or the policy of the Department of Education.

[5] The actual identification and ranking of goals and constraints in Missouri was done in a study by Elbert in 1976. Over 400 administrators, teachers, parents,students were surveyed to come up with the goals and constraints in Table 4.

Table 4

Goals and Constraints: Missouri Application

Ranking	Goals and Constraints	Assigned Priority Level	Deviation to Minimize	Desired Level
Constraints				
1	Limit the number of completers to projected job openings	P1	po_j^+	27,022
2	Limit expenditures on programs to resources available	P1	e^+	81,522
3	Limit those served to 50% of secondary students	P1	b^+	75,727,536
Goals				
1	Realize a 10% increase in the number of completers placed in training-related jobs	P2	r^-	8,065
2	Increase program completers	P3	s^-	23,445
3	Increase labor force participation of completers	P4	f^-	13,689
4	Increase the number of disadvantaged students served by 10%	P5	dh^-	3,600
5	Increase the number of students continuing education	P6	p^-	5,757

$$\sum_{j=1}^{N} L_j X_j - e^+ = PE = 81{,}522 \tag{23}$$

$$\sum_{j=1}^{N} C_j X_j - b^+ = BUD = 75{,}727{,}536 \tag{24}$$

$$\sum_{j=1}^{N} DIH_j X_j + dh^- = DIH = 3{,}600 \tag{25}$$

$$\sum_{j=1}^{N} P_j X_j + r^- = TR = 8{,}065 \tag{26}$$

$$\sum_{j=1}^{N} LEPR_j X_j + f^- = LFP = 13{,}689 \tag{27}$$

$$\sum_{j=1}^{N} A_j X_j + s^- = SS = 23{,}445 \tag{28}$$

$$\sum_{j=1}^{N} BS_j X_j + p^- = CE = 5{,}757 \tag{29}$$

$$X_j \geq 0 \quad (j=1 \ldots N) \tag{30}$$

And the achievement function becomes:

$$\text{Minimize } Z = [3P_1 \sum_{j=1}^{N} PO_j^+ + 2P_1 b^+ + P_1 e^+] + P_2 r^- + P_3 s^- + P_4 f^- + P_5 dh^- + P_6 p^- \tag{31}$$

In words this means that the planning model will allow us to find a mix of programs that minimizes the underachievement of the goals of the system.

Gathering Data

Before the model can be applied, the data needed to derive the technological coefficients in the above objective function equations must be gathered. This was done and the data are presented in Table 5. Obviously, the more accurate the data are, the more confidence one can place in the solution to the application.

The Initial Application

Once the problem is set up and the data gathered, we are ready to apply the model. The complexity of the problem, of course, reqires the use of the computer since the problem would be

virtually impossible to solve otherwise.

The model was applied and the results are presented in Table 6. Five of the eight goals of the vocational education system in Missouri are met. That is, given the relationship between the variables and goals, as expressed in each objective function, the best solution that can be accomplished is represented by the result in Table 6. So the vocational planner would try to implement the program mix that yields this solution since it maximizes the accomplishment of the system's goals. The particular program mix which does so is presented in Table 7. In other words, the solution in Table 7 reflects the distribution of program completers that best accomplish the goals of the vocational education system in Missouri.

Second Application Changing the Priorities of Goals

Although the initial application, previously described, meets the goals and objectives of the vocational education system in Missouri, what happens if the priorities assigned to a goal are changed for some reason or another? To illustrate the effect, priority 2 was assigned to the goal of serving disadvantaged students and priority 5 was assigned to training-related placement. The goal programming model was then applied and the results are presented in Table 8.

The same goals, as in the first application, are accomplished; yet, the final level of each goal is different. There is a decrease in the number of projected job openings filled by the vocational education system. Likewise, there is a decline in the labor force participation of completers. Since the training-related placement goal is no longer the highest priority goal, there is a decrease in the level of this goal.

Finally, as you can see, the highest priority goal of serving disadvantaged students is higher in this application than in the first.

The program mixes for the first and second applications are compared in Table 7. Since the distribution of completions between the two applications differ, the contributions that the program mixes, make toward the accomplishment of the goals of the system are not the same (compare Table 6 and Table 8). The solution to the second application is different because the program mix has changed; that is, the differences in the distribution of completions account for the differences in the final levels of all eight goals in the two solutions. So, it is obvious that a change in priority structures yields different allocation decisions. Alas, I have simply demonstrated what common sense suggests. The essential point is, of course, that the effect of different priority structures on resource allocation decisions can be easily analyzed through the use of the planning model.

Third Application Changing the Value of Constraints

In this application the effect of changing the level of a constraint is examined. The level of funds is increased by $10 million and a solution is found. The results are presented in Table 9. With the additional resources, a total of six goals are accomplished. As expected, the final level of each goal is larger than in the previous applications. Of course, the distribution of program completers reflects the increase in resources (see Table 7). Curiously so, not all of the additional resources are used; in fact, $6 million are not spent. A surplus of funds results because the constraint imposed by projected job openings, limits the number of completions regardless of the additional resources.

By changing the level of funds, or the level of any of the other goals or constraints for that matter, it is possible to simulate the behavior of the vocational system to such changes. Through

Table 5

Technological Coefficients Used

In Missouri Application *

OE Program	P_j	A_j	DIH	C_j	$LFPR_j$	BS_j	PO_j
Production Agriculture	.36	8.33	.09	6524	.55	.24	2504
Agriculture Services	.41	2.32	.07	4180	.56	.13	23
Agriculture Mechanics	.41	2.22	.01	5120	.60	.21	112
Advertising Services	.36	3.12	.01	2106	.51	.23	21
Apparel and Accessories	.37	1.56	.01	2508	.55	.24	583
Automotive	.35	2.04	.08	2342	.47	.16	476
Floristry	.29	2.32	.05	2236	.53	.29	23
Food Distribution	.37	1.79	.06	2570	.43	.21	35
Food Service	.32	1.96	.09	2872	.48	.19	1048
General Merchandise	.25	7.69	.10	2204	.40	.16	148
Hardware, Building Materials	.34	1.69	.08	2052	.52	.27	516
Home Furnishings	.35	1.58	.03	2248	.53	.20	124
Recreation and Tourism	.25	2.94	.08	2304	.33	.25	11
Transportation	.47	2.44	.14	2362	.74	.06	1537
Distribution	.34	2.27	.08	1386	.45	.23	401
Dental Assistant	.51	1.49	.27	1830	.60	.28	68
Practical Nursing	.71	2.78	.79	2854	.78	.04	700
Accounting and Computing	.22	2.44	.05	3030	.36	.34	3760
Data Processing	.28	3.12	.08	2852	.20	.21	321
Clerical Work	.33	1.72	.06	2648	.48	.23	530
Mail and Postal Clerks	.23	2.32	.04	2100	.23	.19	381
Communication Occupations	.23	4.00	.04	2100	.23	.19	326
Secretarial Occupations	.36	1.47	.07	2446	.48	.25	2928
Typing	.28	2.13	.16	2466	.43	.23	1036
Office Occupations	.28	2.13	.16	2000	.43	.23	544
Electrical Technology	.50	3.00	.15	2190	.45	.20	41
Commerical Pilot	.50	2.75	.28	3498	.55	.27	11
Miscellaneous Technical	.50	2.84	.28	2736	.53	.27	12
Air Conditioning	.43	3.38	.05	2310	.73	.03	68
Electrical Appliances	.43	3.72	.04	2672	.76	.03	86
Auto Body	.38	3.23	.05	2202	.66	.10	209
Auto Mechanics	.40	3.03	.09	2310	.63	.12	811
Aircraft Maintenance	.36	3.67	.08	2700	.58	.12	48
Business Machine Repair	.36	2.70	.24	3098	.62	.20	62
Commerical Art	.29	2.35	.04	2284	.51	.16	33
Commerical Photography	.06	2.77	.00	1592	.45	.18	63
Carpentry	.30	3.12	.09	2300	.59	.12	634
Electricity	.48	4.76	.02	2430	.67	.12	265
Masonry	.45	5.55	.35	3046	.78	.13	40
Painting and Decorating	.36	1.63	.08	2350	.58	.12	309
Plumbing and Pipefitting	.28	2.67	.01	2484	.56	.12	169
Clothing Management	.16	6.67	.22	2870	.33	.21	190
Roofing	.36	2.34	.08	2432	.58	.12	11
Drafting	.33	2.63	.12	2544	.53	.23	96
Electrical Occupations	.38	2.94	.09	2128	.66	.08	81
Electronic Occupations	.24	3.03	.04	2250	.43	.27	92
Foremanship	.27	1.67	.02	3248	.61	.15	1067
Graphic Arts	.35	3.48	.07	2836	.60	.12	249
Metal Work	.43	3.33	.05	2672	.64	.06	865
Barbering	.52	2.63	.15	2220	.70	.06	256
Cosmetology	.52	2.63	.15	2300	.70	.06	707
Public Service	.34	2.10	.13	2448	.40	.15	122
Quantity Food Occupations	.40	1.96	.12	1784	.51	.17	68
Stationary Energy Sources	.25	2.65	.00	2418	.45	.20	202
Textile Production	.39	1.19	.27	2284	.52	.16	789
Leather Work	.33	1.67	.00	2008	.45	.20	148
Upholstering	.36	1.45	.08	2008	.58	.12	63
Woodworking	.26	2.34	.08	2282	.63	.12	119
Trade and Industry, Oth	.36	4.34	.08	2300	.58	.12	416

* Source: Missouri Occupational Training Information System

Table 6

Initial Solution: Missouri Application

Goal or Constraint	Priority Level	Achieved	Deviation from Goal	Final Level
Constraints				
• Projected job openings	P1	Yes	- 855	26,167
• Limit on enrollment	P1	Yes	- 24,095	57,426
• Limit on funds	P1	Yes	-0-	75,727,536
Goals				
• Training-related placements	P2	Yes	+ 989	9,054
• Number of completers	P3	Yes	+ 1,721	26,167
• Labor force participation	P4	No	- 146	13,167
• Disadvantaged completions	P5	No	- 876	2,724
• Continuing education	P6	No	- 634	5,123

Table 7

Distribution of Completions Resulting from

Application of Model

OE Program	Initial Application	Second Application	Third Application
Agriculture Services	23	23	23
Agriculture Mechanics	44	44	44
Production Agriculture	2488	2596	2872
Advertising Services	21	21	21
Apparel and Accessories	510	510	510
Automotive	476	476	476
Floristry	23	23	23
Food Distribution	833	833	833
Food Service	35	35	35
General Merchandise	148	148	148
Hardware, Building Materials	516	516	516
Home Furnishings	124	124	124
Petroleum	56	56	56
Recreation and Tourism	11	11	11
Transportation	1537	1537	1537
Distribution	401	401	401
Dental Assistant	68	68	68
Practical Nursing	700	700	700
Radiologic Technician	0	0	0
Health Occupations	281	281	281
Accounting and Computing	3760	3760	3760
Data Processing	79	0	321
Clerical Work	530	530	530
Mail and Postal Clerks	381	381	381
Communication Occupations	326	326	326
Secretarial Occupations	2867	2867	2856
Typing	960	960	960
Office Occupations	473	473	473
Electrical Technology	41	41	41
Commerical Pilot	11	11	11
Miscellaneous Technical	12	12	12
Air Conditioning	68	68	68
Electrical Appliances	86	86	86
Auto Body	109	109	109
Auto Mechanics	671	671	796
Aircraft Maintenance	48	48	48
Business Machine Maintenan .e	17	17	17
Commerical Art	33	33	33
Carpentry	634	634	634
Electricity	265	265	265
Masonry	40	40	40
Painting and Decorating	309	309	309
Plumbing and Pipefitting	169	169	169
Roofing	11	11	11
Maintenance Trades	119	119	119
Drafting	95	95	95
Electrical Occupations	81	81	81
Electronic Occupations	207	207	207
Graphic Arts Occupations	249	249	249
Metal Working	865	865	865
Barbering	256	256	256
Cosmetology	707	707	707
Public Service	12	12	12
Quantity Food Occupation	68	68	68
Stationary Energy Sources	202	202	202
Textile Production	789	789	789
Leatherworking	293	148	293
Trade and Industry, Other	416	416	416
Foremanship	1067	1067	1067
Woodworking	148	0	148
Clothing Services	300	305	405
Commerical Photography	63	27	63
Total Completions	26,167	25,966	27,022

Table 8

Solution to Second Application

Goal or Constraint	Priority Level	Achieved	Deviation from Goal	Final Level
Constraints				
Projected job openings	P1	Yes	- 1,056	25,966
Limit on enrollment	P1	Yes	- 23,662	57,860
Limit on funds	P1	Yes	-0-	75,727,536
Goals				
Disadvantaged students	P2	No	- 854	2,856
Number of completers	P3	Yes	- 1,821	25,966
Labor force participation	P4	No	- 170	13,529
Training-related placements	P5	Yes	737	8,802
Continuing education	P6	No	- 781	4,976

Table 9

Solution to Third Application

Goal or Constraint	Priority Level	Achieved	Deviation from Goal	Final Level
Constraints				
• Projected job openings	P1	Yes	-0-	27,022
• Limit on enrollment	P1	Yes	- 21,599	59,923
• Limit on funds	P1	Yes	- 5,272,339	80,000,197
Goals				
• Training-related placements	P2	Yes	+ 1,254	9,319
• Number of completers	P3	Yes	+ 2,576	27,022
• Labor force participation	P4	Yes	+ 174	13,802
• Disadvantaged students	P5	No	- 760	2,840
• Continuing education	P6	No	- 427	5,331

simulation, then, experiments on the system can be performed without the risk or expense accompanying experiments on the actual system; thus, different plans can be tried before they are implemented.

Conclusions

In this paper I have described a planning model for vocational education. This model, as illustrated, links an analytical technique to the computer and brings them to bear on the problem of planning vocational education. The model was developed by building a mathematical model applicable to the sort of planning decisions that vocational administrators at the state level typically make. The result, of course, is a generalizable planning model that has the potential of being used from one state to another.

By extending the discussion of the formulation of the mathematical model, I hoped to convey the essentials needed to mathematically represent a vocational education system.

I do think, though, that the example of the application in Missouri does present quite clearly the capability this system offers. Its capabilities include thing like: solving planning problems involving multiple and conflicting goals; simulating the effect that different plans have on the system; and understanding the relationship among various goals, variables and constraints.

But let us be realistic too. Neither analytical techniques nor the computer are the ultimate solution to improved planning, for the decision maker's judgment can never be replaced entirely by such methods. They can, though, improve one's capability to make decisions.

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